Original Article

Survival estimates and risk factors for failure of palatal and buccal mini-implants

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ABSTRACT

Objectives: The primary objective was to compare the success and survival rates of palatal and buccal mini-implants for different locations and treatment requirements. The secondary objective was to evaluate risk factors influencing the survival of mini-implants.

Materials and Methods: In this retrospective cohort, records of 127 orthodontic patients with 257 mini-implants were included after imposing inclusion/exclusion criteria. Along with the implant failure data, factors such as age, sex, transverse location, anteroposterior location, and purpose of mini-implants were recorded. Kaplan–Meier survival analysis was used to draw the curves and a Nathan Mantel-David Cox test to compare variables.

Results: The failure rate of palatal mini-implants was 8.5%, whereas the failure rate for buccal shelf mini-implants was 68.7% ($P < .0001$). A significant difference was that the survival rates of palatal mini-implants were dependent on the purpose of the mini-implants and, for the buccal mini-implants, they were dependent on the skeletal malocclusion and location type of mini-implants ($P < .05$).

Conclusions: The overall survival rate of palatal mini-implants was high, at 91.5%. Of the buccal mini-implants, inter-radicular mini-implants had the highest survival rate for 12 (75.5%) and 24 (71.9%) months, while buccal shelf mini-implants had the lowest success and survival rates for 12 (31.3%) and 24 (20.8%) months. Class III malocclusion had the lowest survival rate for the buccal mini-implants (65.3% and 54.2%) for 12 and 24 months. (*Angle Orthod.* 2021;91:756–763.)

KEY WORDS: Mini-implants; Survival rates

INTRODUCTION

Mini-implants have effected a change in the envelope of tooth movement that can be achieved with orthodontic biomechanics.[1] The small size of the mini-implants makes them a versatile option to be used in different sites in the maxilla and mandible to achieve the desired orthodontic tooth movement.[2] Mini-implants were initially used for orthodontic patients with high anchorage requirements for maximum retraction of anterior teeth in extraction cases.[2,3] With a growing knowledge regarding the biomechanics of mini-implants for orthodontic purposes, the landscape of orthodontic mini-implants has expanded to include complex tooth movements such as distalization, expansion, uprighting, intrusion, extrusion, and protraction.[3]

The success rates of mini-implants have been reported to be high with approximately 84% success.[4,5] However, there is a significant difference in the success rates between different locations of mini-implants in the jaws.[3] The maxillary and mandibular interradicular region is a popular site for mini-implants as a result of the ease of placement and application of direct orthodontic force. However, interradicular mini-implants in the posterior zone have a high failure rate of about 20% to 29%.[6,7] Because of this, palatal mini-implants have gained popularity during the past few years.[8,9] Palatal mini-implants are commonly used for

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appliances designed for rapid palatal expansion. Parasagittal insertion of the mini-implants in the palate is a preferred site for miniscrew-assisted rapid palatal expansion. However, for other orthodontic purposes such as distalization, intrusion, and anchorage control during retraction of the anterior teeth, various designs of mini-implants either in the palatal or buccal region have been described.[2,3,10,11]

The high success rate and ease of placement has led to a surge in the use of mini-implants in orthodontics in the recent years. Thus, a better understanding of the success rates of mini-implants depending on the location of insertion and the purpose of the mini-implants would be valuable clinically in treatment planning. Different locations of mini-implants can be used to achieve the same orthodontic tooth movements. For example, retraction of the maxillary anterior teeth can be performed with either buccal mini-implants or palatal mini-implants. However, depending on the location of the mini-implants, the orthodontic biomechanics have to be altered by clinicians to achieve the desired tooth movement.[10,11]

The objectives of this study were to compare the success rates of palatal and buccal mini-implants for different locations and treatment requirements. In addition, the influence of type of malocclusion, sex, and age on the success rates of mini-implants was also evaluated. Another objective of the study was to evaluate a number of risk factors influencing the survival of mini-implants.

MATERIALS AND METHODS

In this retrospective study (approved by the institutional review board [20X-173-1]), a database of the UConn Health Division of Orthodontics was reviewed to identify patients with mini-implants. A total of 127 patients were identified with a total of 275 mini-implants. Multiple orthodontic residents and faculty members placed mini-implants, but the operator's experience was not considered in the overall analysis. All of the mini-implants were 2 mm in diameter and 8 or 10 mm in length (3M Unitek [Monrovia, Calif] and Forestadent [Pforzheim, Germany]).

Orthodontic patients at UConn Health with any type of malocclusion that required palatal or buccal mini-implants for treatment were included in the study. No age, sex, or racial restrictions were applied. Patients with missing data, records, or notes from the database were excluded from the study. Data collection included the date of placement, failed or not; date of failure; or date of removal. Based on these data, the duration of mini-implants was calculated in months. Because the study also aimed to evaluate the factors influencing the survival rate of mini-implants, age, sex, transverse location (palatal mini-implants: paramedian or sutural), anteroposterior location (mesial to canine, canine to the second premolar, or distal to the second premolar), location type of buccal mini-implants (interradicular, infrazygomatic, or buccal shelf), and the purpose of mini-implants (indirect anchorage, distalization, expansion, intrusion, or protraction) were also considered.

Statistical Analysis

Nonparametric tests such as the Mann-Whitney test (for a group of two: sex, side, arch) and Kruskal-Wallis test (for a group of three or more: age, tooth level, malocclusion, purpose, and location) were conducted to evaluate the level of significance. Kaplan-Meier survival analysis was used to draw the curves, and a log-rank (Nathan Mantel-David Cox) test was used to compare variables (age, sex, maxillary or mandibular arch, right or left side, anteroposterior location, type of malocclusion, reason for mini-implants, location type of mini-implants). As duration was considered in the analysis, the day of the mini-implant placement was marked as zero. A P value $<.05$ was deemed statistically significant. Krippendorff's α was calculated for interrater agreement. Statistical analyses were computed using Graph Pad software (La Jolla, Calif).

RESULTS

Krippendorff's α was 0.87, 0.95, and 0.81 and showed excellent interrater agreement for the mini-implant failure (yes/no), location of mini-implant (buccal alveolar, infrazygomatic, or buccal shelf), and purpose of mini-implants, respectively. Table 1 describes the age and sex distribution of the buccal and palatal mini-implants. The distribution of mini-implants based on different variables is reported in Table 2. Survival analysis of the buccal and palatal mini-implants was conducted separately, and based on the data, subgroup analysis was then performed with different variables.

Survival Analysis (Palatal Mini-Implants)

The success rate of palatal mini-implants was 91.5% (108 of 118), and the failure rate was 8.5% (10 of 118). The survival analysis indicated no significant difference between male and female patients ($\chi^2 = 3.201$, P value $= .074$), and the 12-month survival rates were 95.5% for male patients and 86.8% for female patients (Figure 1A). Similarly, the survival analysis indicated no significant difference between paramedian and sutural regions ($\chi^2 = 0.093$, P value $= .761$), and the 12-month survival rates were 90.8% for the paramedian region and 92.9% for the sutural region (Figure 1B).

Table 1. Age and Sex Distribution of the Palatal and Buccal Mini-Implants

	Palatal Mini-Implants			Buccal Mini-Implants		
Sex	Patients, N	Mini-Implants, N (%)	Mean ± SD Age, Years	Patients, N	Mini-Implants, N (%)	Mean ± SD Age, Years
Overall	62	118 (100)	23.7 ± 11.9	65	157 (100)	29.95 ± 12.7
Female	34	63 (53)	24.3 ± 13.4	33	99 (63)	31.6 ± 13.7
Male	28	55 (47)	23 ± 9.9	32	58 (37)	26.73 ± 11.1

Comparison of the anteroposterior location of mini-implants showed no significant difference between groups ($\chi^2 = 3.074$, P value = .215). The 12-month survival rates were 100% for mini-implants placed mesial to the canine, 95.2% for mini-implants placed between the canines and second premolars, and 84.9% for mini-implants placed distal to the second premolars (Figure 1C).

Table 2. Distribution of Buccal and Palatal Mini-Implants Based on Different Variables

Variable	N (%)
Palatal mini-implants	
Transverse location	
Paramedian	104 (88)
Midline	14 (12)
Anterioposterior location	
Mesial to canine	4 (3)
Canine to second premolar	63 (53)
Distal to second premolar	51 (43)
Purpose of mini-implants	
Anchorage	18 (14)
Distalization	22 (16)
Expansion	36 (27)
Intrusion	27 (20)
Protraction	31 (23)
Buccal mini-implants	
Arch	
Maxilla	65 (41)
Mandible	92 (59)
Location type	
Buccal alveolar	130 (83)
Infrazygomatic	11 (7)
Buccal shelf	16 (10)
Purpose of mini-implants	
Retraction	55 (41)
Protraction	40 (29)
Distalization	21 (15)
Intrusion	17 (13)
Anchorage	2 (2)
Angle's classification	
Class I	67 (45)
Class II	45 (30)
Class III	37 (25)
Anterioposterior location	
Mesial to canine	5 (3)
Canine to second premolar	35 (23)
Second premolar to second molar	111 (71)
Distal to second molar	5 (3)
Age group	
0–20 y	44 (28)
21–40 y	79 (50)
41–65 y	34 (22)

There was a significant difference ($\chi^2 = 10.76$, P value = .029) in the survival rates of the mini-implants based on the treatment requirements (anchorage, distalization, expansion, intrusion, and protraction). The 12-month survival rate was lowest for distalization (70.1%) and expansion (81%), followed by anchorage (88.5%) and intrusion (92.6%), and was highest for posterior segment protraction (100%) (Figure 1D).

Survival Analysis (Buccal Mini-Implants)

Of 157 buccal mini-implants, 51 (32.5%) mini-implants were lost during the observation period. The survival rate for the 157 mini-implants was 67.5%. Distribution of the failure rates of different buccal implants is provided in Figure 2.

The survival analysis indicated a significant difference between male and female patients ($\chi^2 = 6.482$, P value = .011). The 12-month survival rates were 68.4% for males and 80.2% for female patients, whereas the 24-month survival rates were 60.2% for male patients and 80.2% for female patients (Figure 3A).

No significant difference was found in the survival rate of mini-implants among age groups ($\chi^2 = 1.08$, P value = .583) (Figure 3B). In addition, there was no significant difference when comparing maxillary and mandibular buccal mini-implants ($\chi^2 = 2.467$, P value = .1153). The 12-month survival rates were 82.6% for the maxillary arch and 70.4% for the mandibular arch; the 24-month survival rates were 77.1% for the maxillary arch and 68.3% for the mandibular arch (Figure 3C).

A significant difference was found among the patients with different types of malocclusions (Angle classification) ($\chi^2 = 7.876$, P value = .02). The 12-month survival rates were 74.4% for Class I, 86.7% for Class II, and 65.3% for Class III subjects; the 24-month survival rates were 74.4% for Class I, 82.1% for Class II, and 54.2% for Class III subjects (Figure 3D). The right and left sides did not show any significant difference in the mini-implant survival rates ($\chi^2 = 0.143$, P value = .706).

Comparison by the anteroposterior location of mini-implants showed no significant difference among the groups ($\chi^2 = 0.2945$, P value = .9611). The 12-month survival rates were 80% for the mini-implants placed in the region mesial to the canine, 75.4% for canines to second premolars, 75.3% for second premolars to

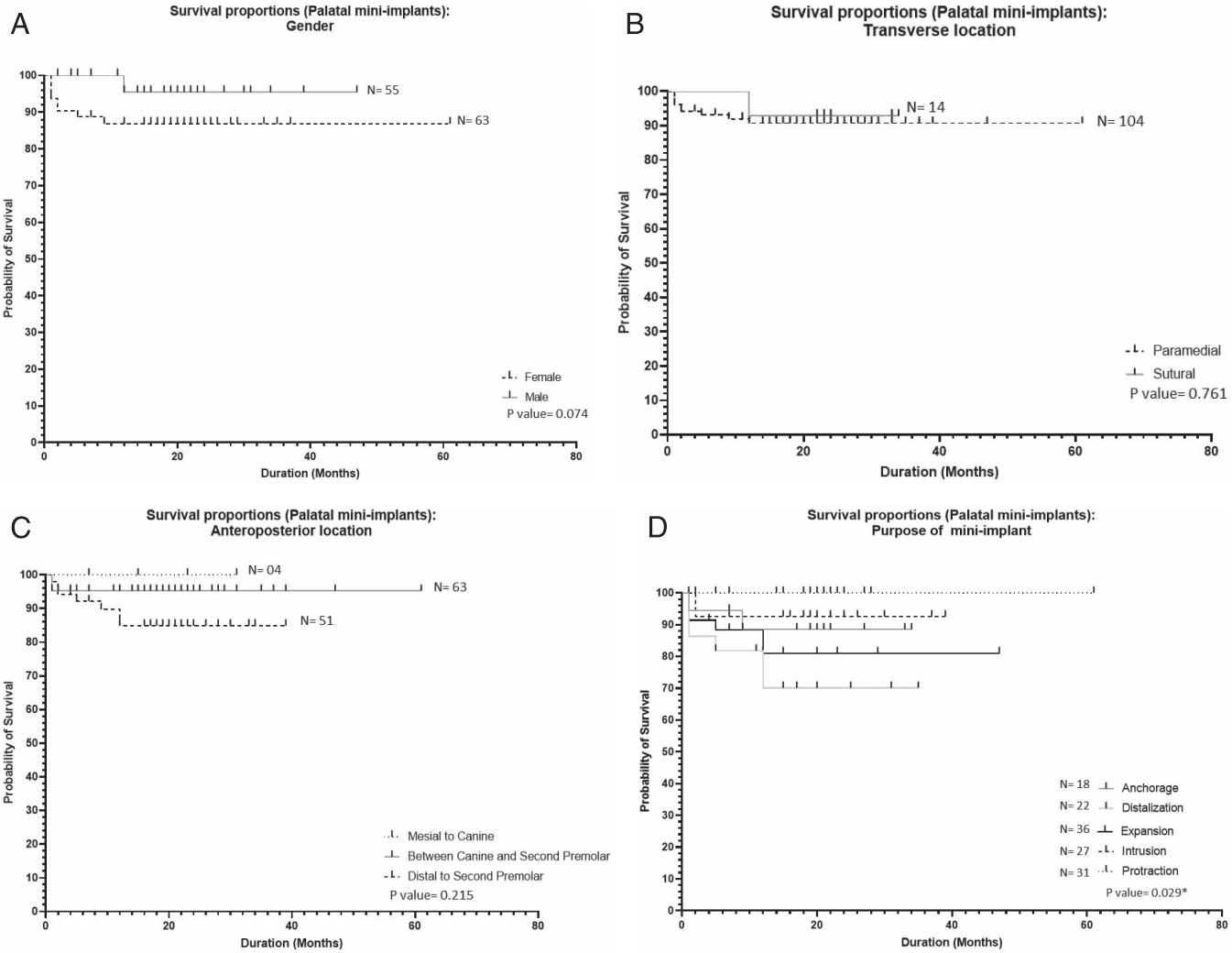

Figure 1. Kaplan-Meier estimates of survival rates of palatal mini-implants in male and female patients: (A) sex, (B) transverse location, (C) anteroposterior location, and (D) purpose of mini-implants.

second molars, and 66.7% for distal to the second molar region. The 24-month survival rates for the mini-implants were 80% for mesial to the canine, 71% for canines to second premolars, 71.8% for second premolars to second molars, and 66.7% for distal to the second molar region (Figure 3E).

Comparison of survival rates among location types of mini-implants (buccal alveolar, infrazygomatic, buccal shelf, and palatal mini-implants) showed a significant difference ($\chi^2 = 49.84$, P value $< .0001$). The 12-month survival rates were 75.5% for buccal alveolar, 72.7% for infrazygomatic, 31.3% for the buccal shelf, and 90.9% for the palatal region; the 24-month survival rates were 71.9% for buccal alveolar, 63.6% for infrazygomatic, 20.8% for the buccal shelf, and 90.9% for the palatal region (Figure 3F).

Comparison of the survival rates based on the purpose of buccal mini-implants (retraction, protraction, distalization, intrusion, and anchorage) revealed no significant differences ($\chi^2 = 6.298$, P value $= .178$). The 12-month survival rate was the lowest for distalization (54%), followed by intrusion (76.5%), retraction (77.9%), and protraction (79.6%), and was the highest for anchorage (100%). The 24-month survival rate for retraction was 77.9%, for protraction was 75.4%, for distalization was 54%, for intrusion was 51%, and for anchorage was 100% (Figure 3G).

DISCUSSION

Because of the increasing popularity of mini-implants in clinical orthodontics, the evaluation of the survival rates of mini-implants is valuable to clinicians. The success rate of mini-implants has been reported to be positively correlated with the anatomy of the insertion site, age, sex, type of malocclusion, and purpose of mini-implants.[12] The overall success rates for the mini-implants was observed to be 79.5% in the current

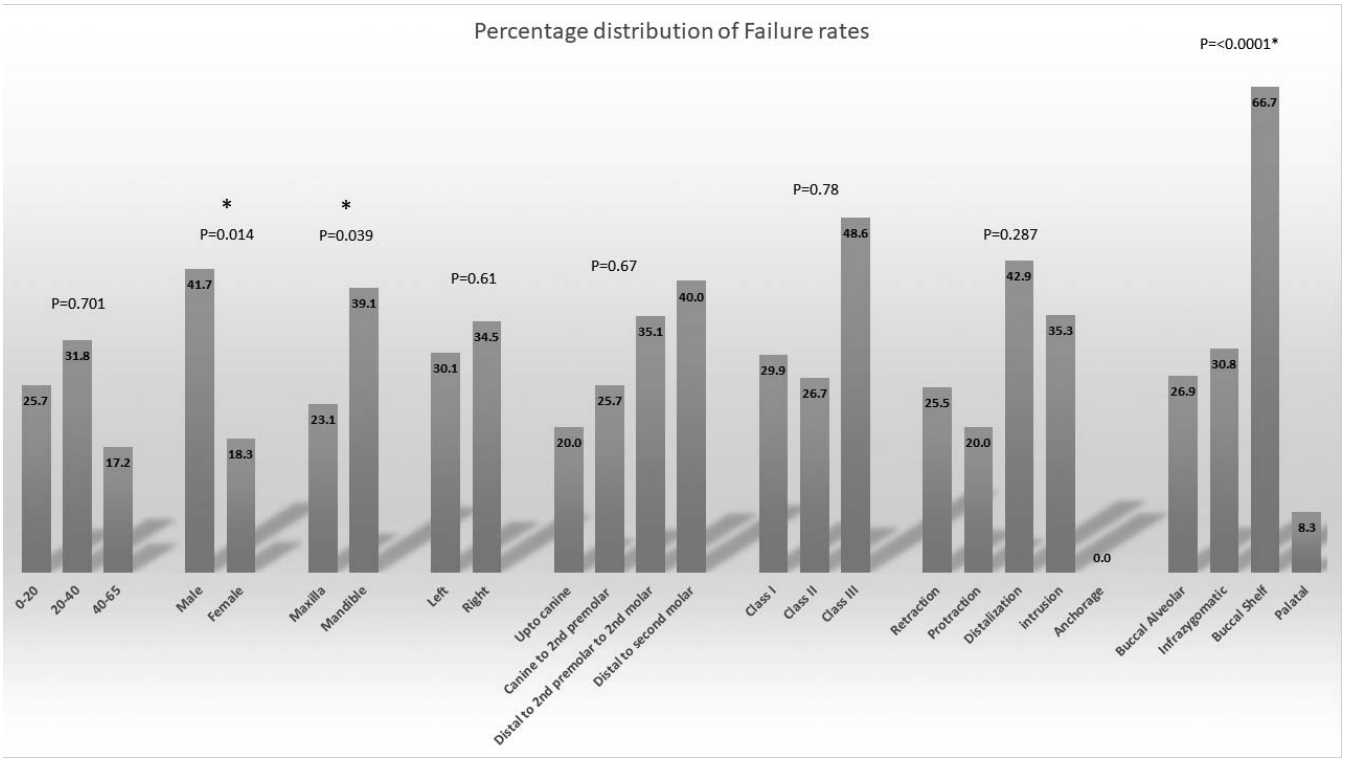

Figure 2. Distribution of the failure rates of buccal mini-implants based on age groups, sex, dental arch, side, anteroposterior location, type of malocclusion, purpose, and location type of mini-implants.

study. The results were within the range that was reported in other investigations.[4,5]

The success rate of palatal mini-implants was 91.5%, which was comparable with that reported in the literature as ranging from 98.2% to 91%.[13] The palatal region can be considered as a preferred anatomic location for mini-implants as it contains adequate bone stock and keratinized soft tissue. In addition, the chances of root injury with palatal mini-implants are minimal, and the location is not in the path of orthodontic tooth movement, allowing simplified mechanics to be used for complex malocclusions.[14] In a majority of cases, two or more palatal mini-implants are used depending on the treatment requirements, and this provides a larger surface area for the load distribution, resulting in higher stability.[13]

The magnitude of forces and the purpose of the mini-implants significantly influenced the success rates. High survival rates were observed for palatal mini-implants when used for molar protraction (100%). This could be attributed to the anterior location (between first premolar and canine) of the mini-implant, where the bone stock is of good quality.[14] It was observed that the 12-month survival rates for mini-implants used for distalization were significantly lower. In addition to the bone quality and quantity, various host factors such as the magnitude of forces and oral hygiene could have led to the lower survival rates (Figure 1D).[13,14] In addition, the survival rate for mini-implants for molar intrusion was approximately 93%. It appeared that the low range of orthodontic force required for molar intrusion resulted in a high survival rate. However, the survival rate for the mini-implants used for expansion was significantly lower. High magnitudes of forces greater than 10,000 gm have been reported with rapid palatal expansion appliances.[15] Such high force loads on the mini-implants could lead to higher failure rates. Orthodontic forces are influenced by the treatment objectives and the purpose of the mini-implants. It has been reported that moderate loading forces were tolerated well by orthodontic mini-implants.[16] The current study confirmed this finding, as the success rates of mini-implants were influenced by their orthodontic purpose.

Aside from the purpose of palatal mini-implants, sex, transverse (paramedian vs sutural), or anteroposterior location did not show a significant effect on the survival rates of palatal mini-implants. These results were in agreement with the published work of Asscherickx et al., in which the factors affecting the success of palatal mini-implants ($n = 34$) were evaluated; however, that study evaluated significantly less palatal mini-implants compared with the current study.[17] There was a statistically significant difference between males and females for the buccal mini-implants, with a higher survival rate in females than males (80.2% vs 68.4%)

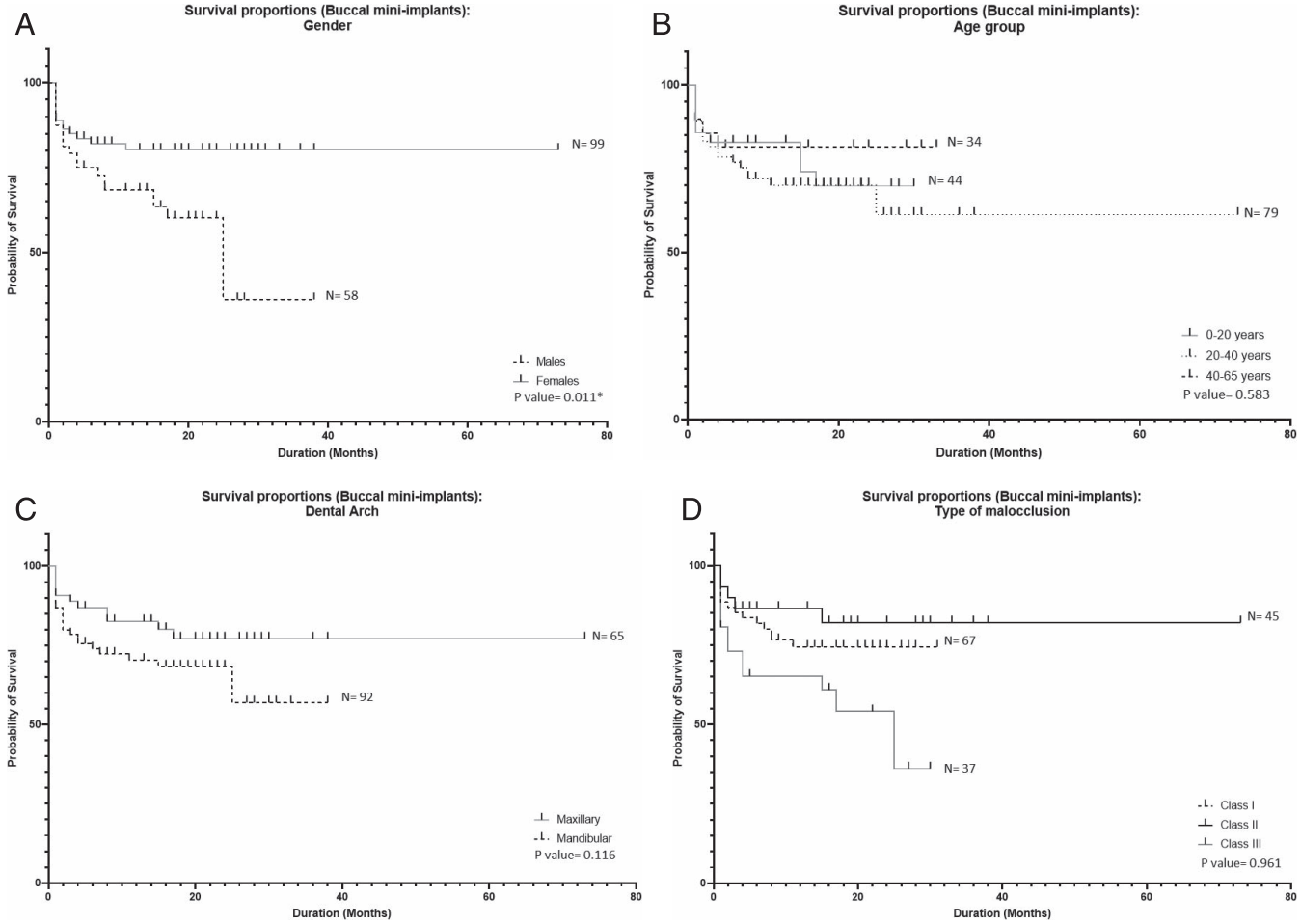

Figure 3. Kaplan-Meier estimates of survival rates of buccal mini-implants placed in paramedial or sutural locations: (A) sex, (B) age group, (C) dental arch, (D) type of malocclusion, (E) anteroposterior location, (F) location type of mini-implants, and (G) purpose of mini-implants.

(Figure 3A). These findings were similar to those reported by Miyawaki et al., who observed higher success rates of titanium screws in females.[9] These findings could be attributed to anatomic and hormonal differences.[18] The Kaplan-Meier graph comparing age groups showed that the success of mini-implants was not significantly affected by age. This was the opposite of the observation by Tsai et al. based on an analysis of 254 mini-implants, who found a positive correlation of failure with age in patients older than age 30 years compared with patients aged 20 to 30 years.[19] Even though the bone density and thickness are dissimilar in individuals of different age groups, multiple other factors including the purpose and the location of mini-implants can also play a role in their success.

The mini-implants placed on the buccal side had 12-month and 24-month survival rates of 82.6% and 77.1% for the maxillary and 70.4% and 68.3% for the mandibular arch, respectively (Figure 3C). These findings were supported by Papageorgiou et al., in which a significantly higher mini-implant failure in the mandible (19.3%) than the maxilla (12%) was found.[20] Increased thickness and density of mandibular cortical bone requires high torque for mini-implant insertion, which leads to high friction and a higher failure rate compared with the maxillary arch.[20]

Aside from the purpose of mini-implants, the type of skeletal malocclusion and insertion site resulted in statistically significant differences in survival. The mini-implants in patients with Class III malocclusions had approximately 20% lower success rates than in Class II malocclusions. These findings can be explained by understanding the type of mechanics used with mini-implants. A majority of the mini-implants inserted in the Class II patients were used for retraction of the maxillary anterior teeth, whereas most of the mini-implants in the Class III patients were placed in the buccal shelf or retromolar pad areas for distalization of the entire lower arch.

In summary, the success and survival rates of different types of mini-implants were assessed in this retrospective cohort study with a large sample. The

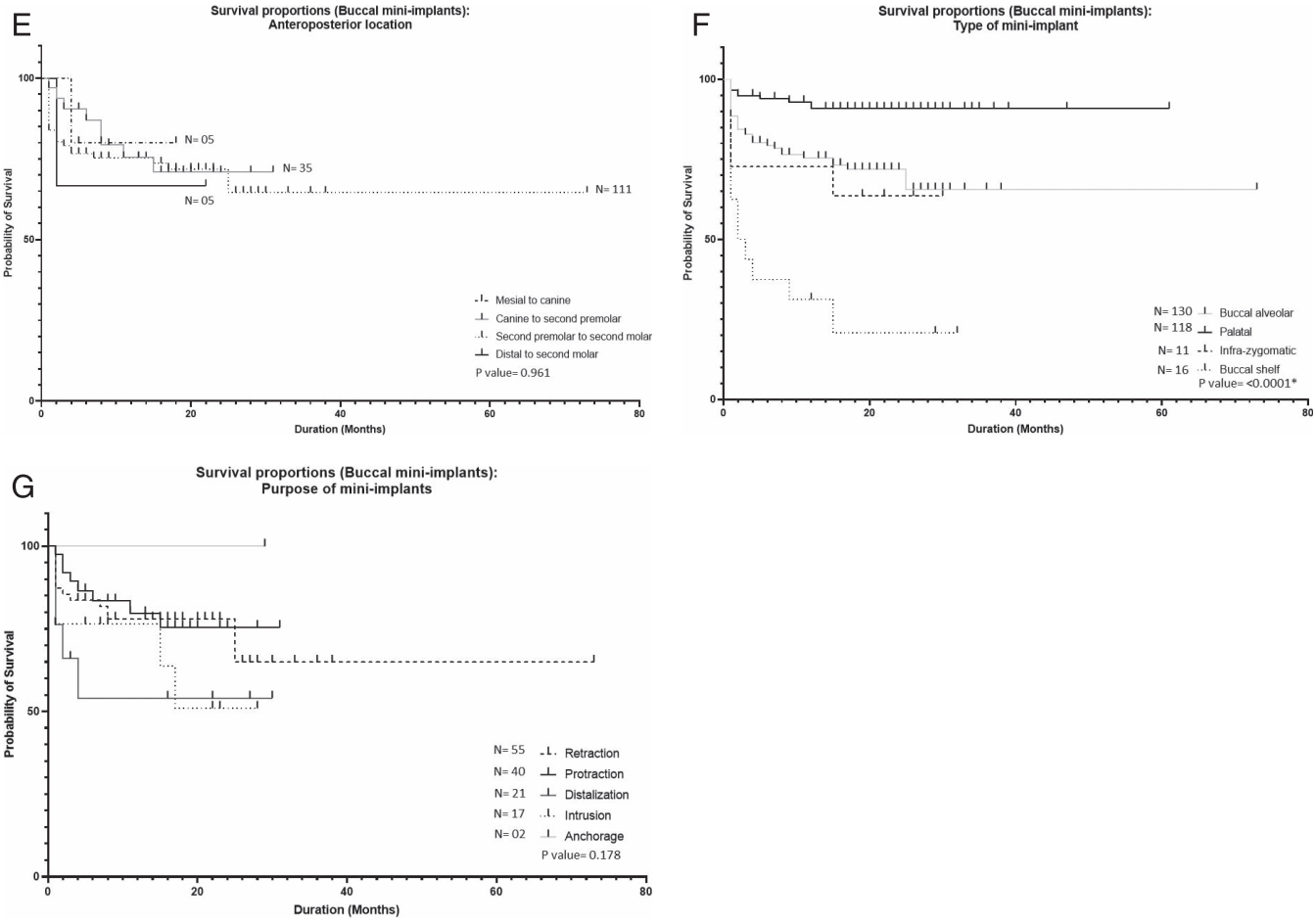

Figure 3. Continued.

palatal mini-implants showed the highest success (91.7%) and survival rates (both at 12 months and 24 months), whereas the buccal shelf mini-implants showed the highest failure rate (66.7%) (Figure 3F). One limitation of the study was its retrospective design. Further investigations such as multicentered randomized controlled trials should be conducted to help clinicians use mini-implants effectively and efficiently with minimal failure.

CONCLUSIONS

- The overall survival rate of palatal mini-implants is as high as 91.5%. Sex and location (transverse or anteroposterior) do not influence the survival of palatal mini-implants.
- The biomechanical purpose of mini-implants has a significant effect on the survival rate of palatal mini-implants. Palatal mini-implants used for distalization have the lowest, and those used for protraction have the highest, 12-month survival rates.
- For buccal mini-implants, dentoalveolar implants have the highest, and buccal shelf mini-implants the lowest, success and survival rates (12 and 24 months).
- Class III malocclusion has the lowest survival rate for buccal mini-implants.

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